USGS
science for a changing world

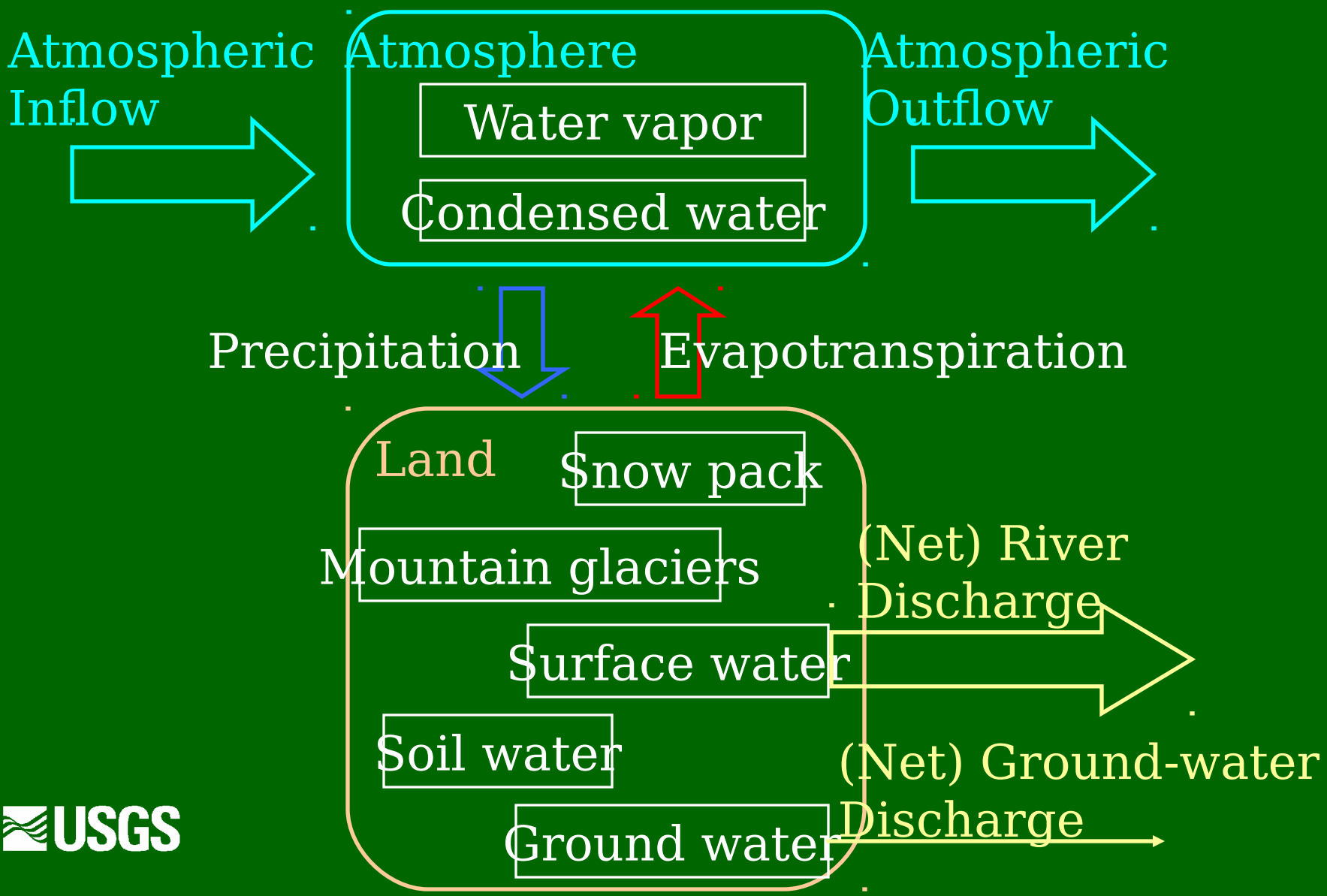
Manifestations of Climate Change in Annual-Mean Runoff and Streamflow, with a Focus on the United State

Christopher Milly, USGS

"Climate Change and Water Resources"
U.S. Army Corps of Engineers—U.S. Geological Surv
Joint Headquarters Meeting
Washington, DC
May 31, 2007

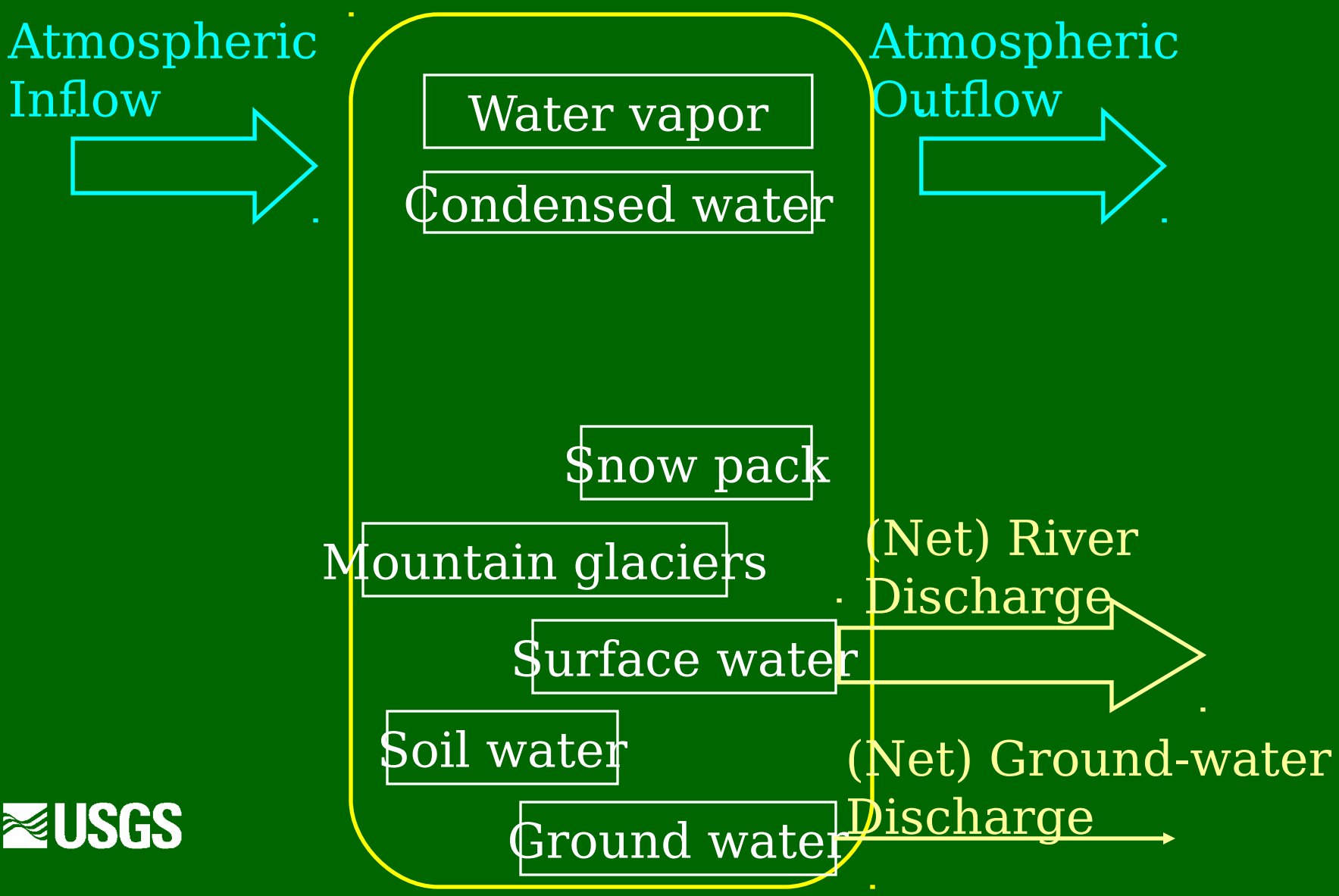
U.S. Department of the Interior
U.S. Geological Survey

Atmosphere-Land Column Water Balance

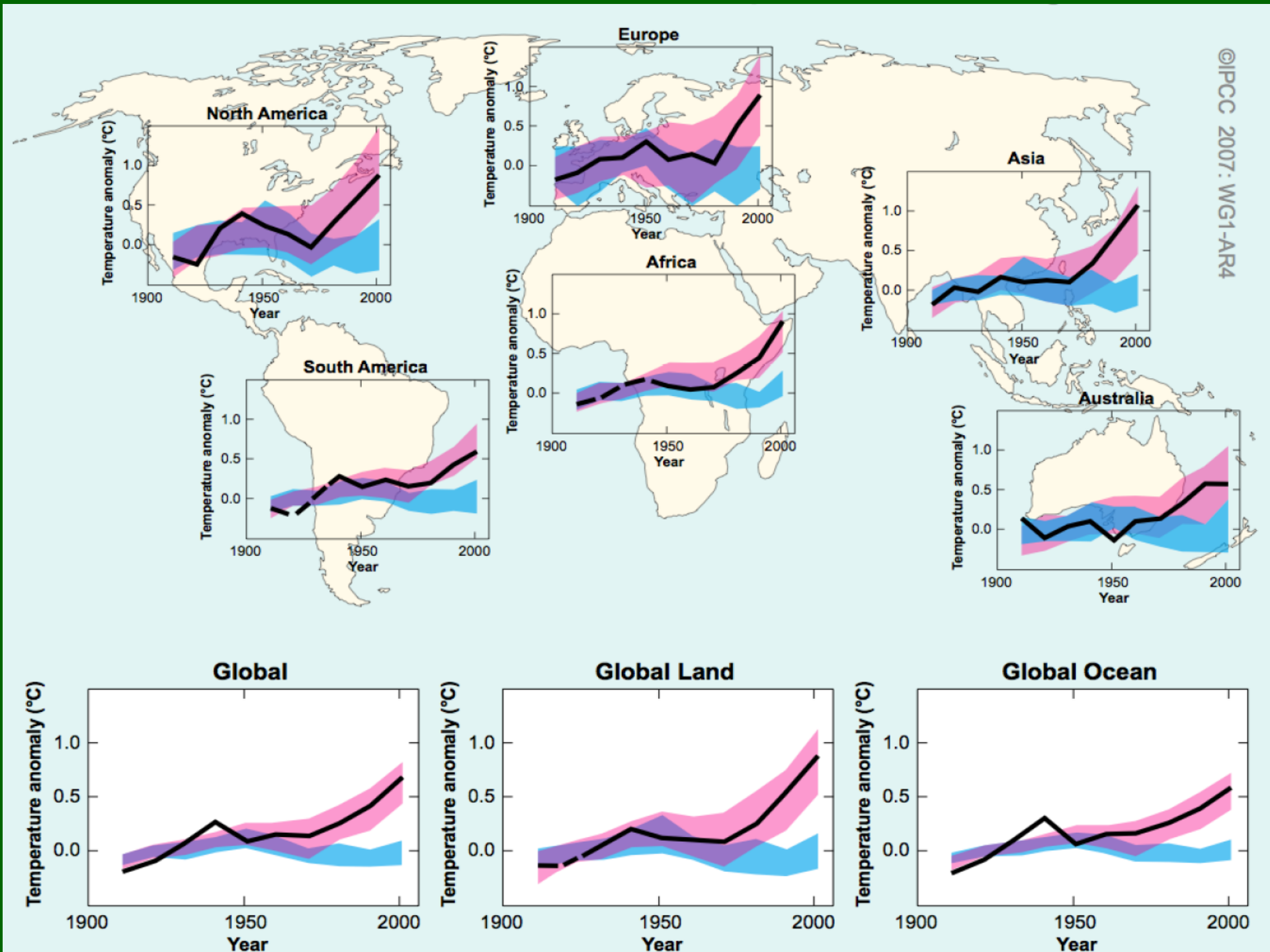


USGS

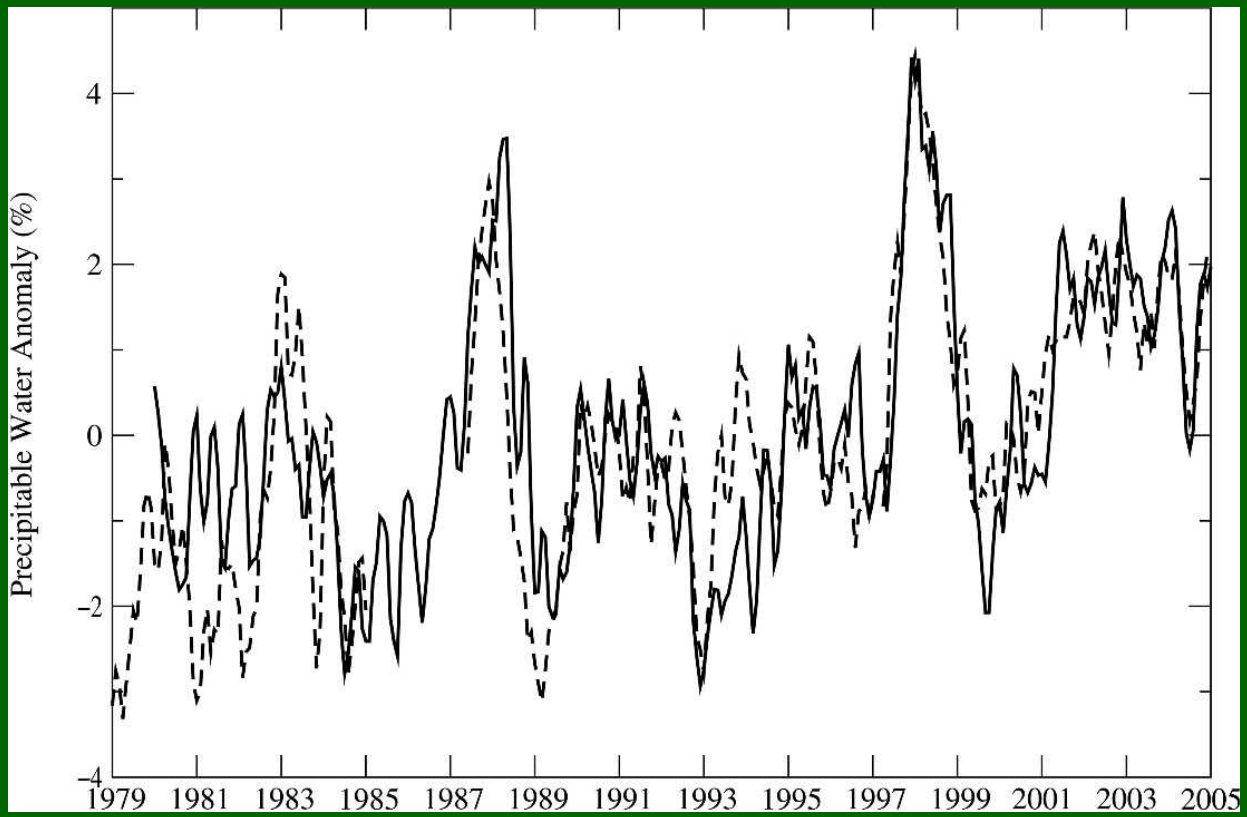
Atmosphere-Land Column Water Balance



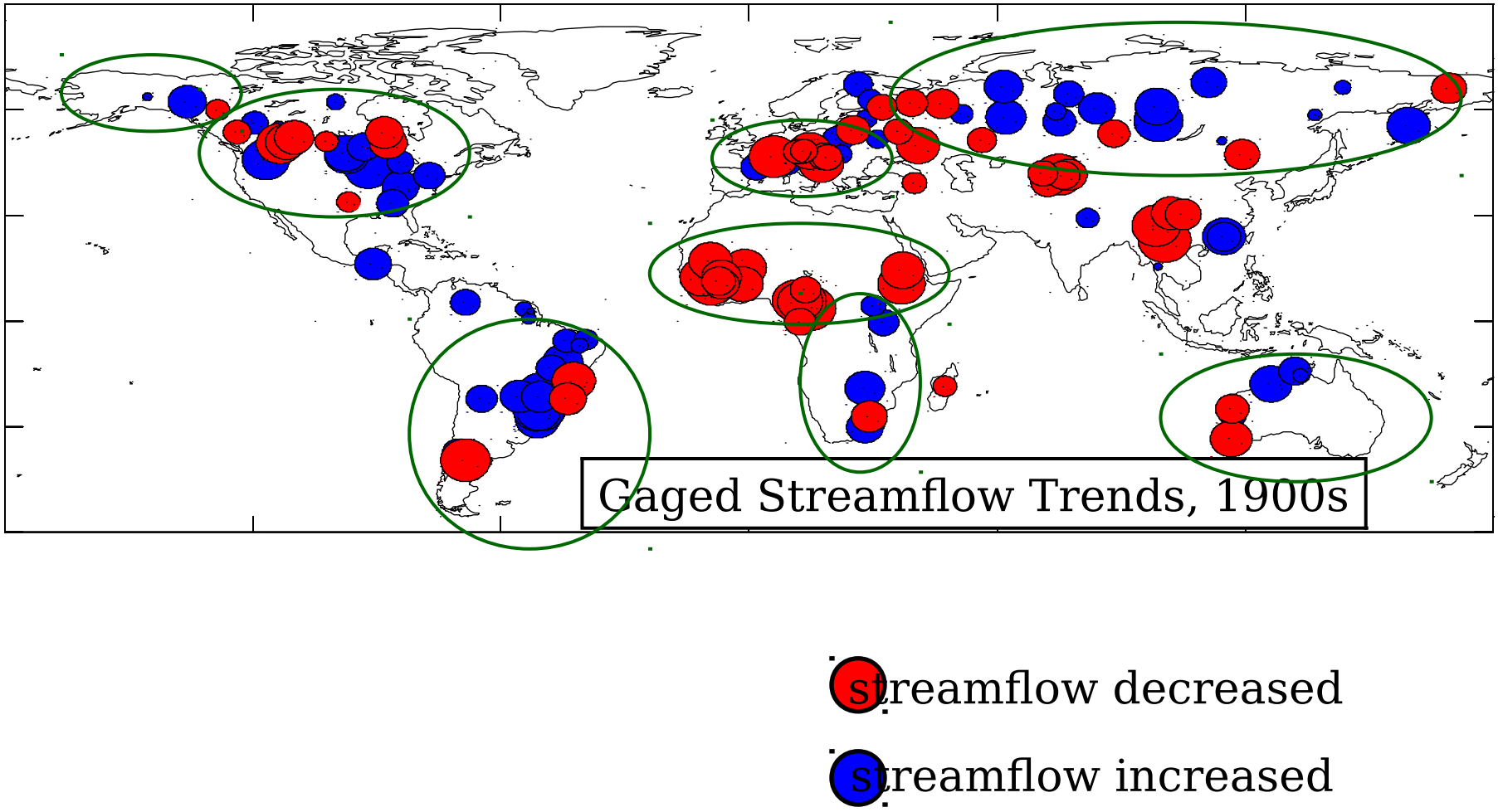
USGS

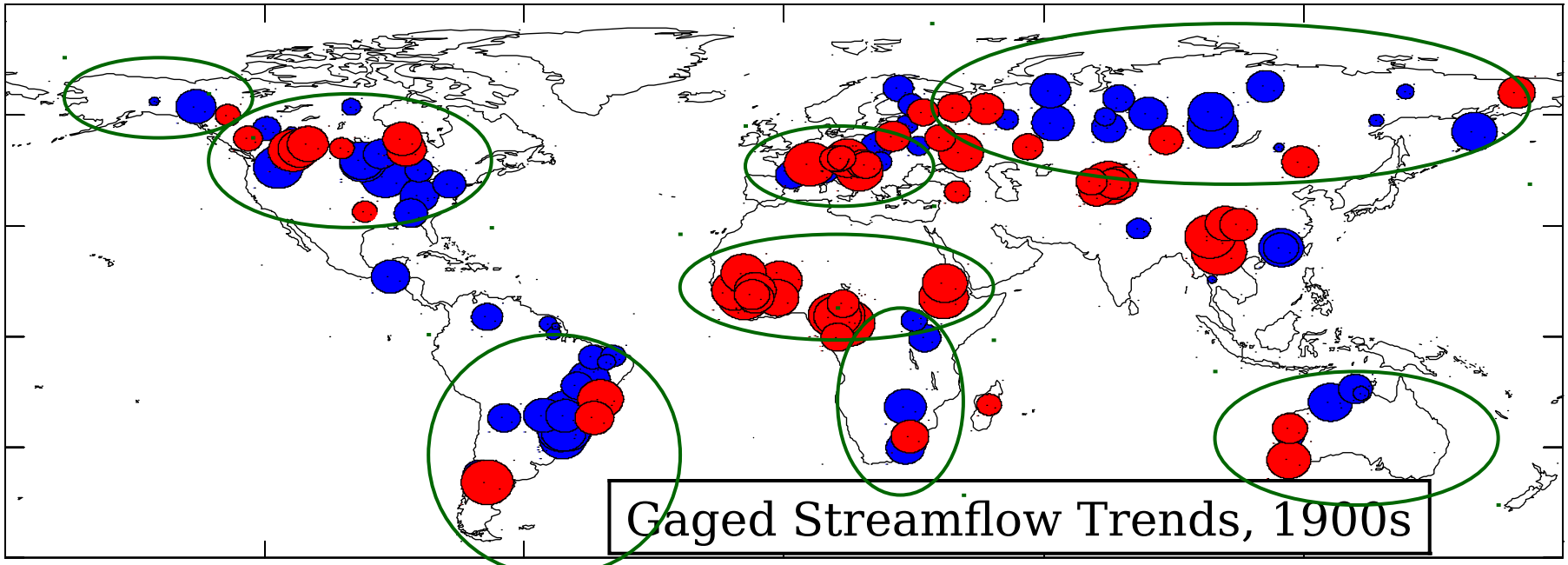

Europe
North America
Asia
Africa
South America
Australia
Temperature anomaly (°C)
1.0
0.5
0.0
1900
1950
2000
Year
©IPCC 2007: WG1-AR4
Global
Global Land
Global Ocean

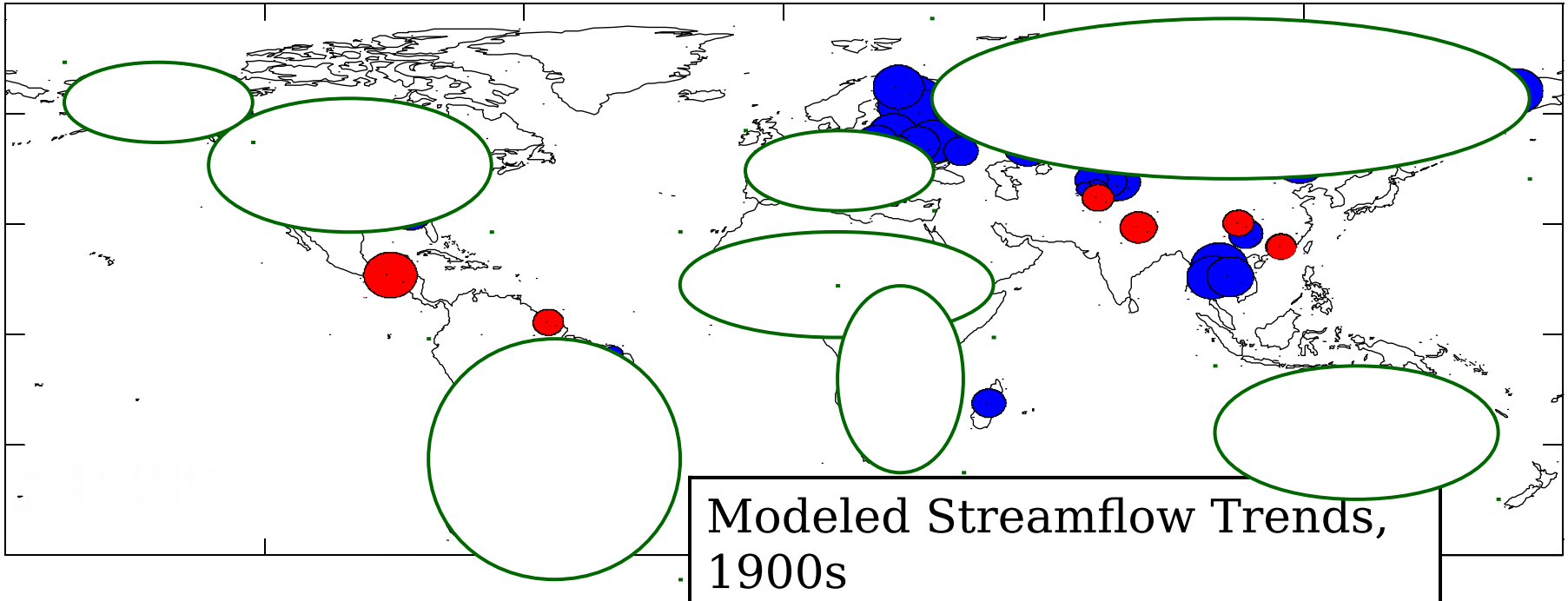
Robustness of Hydrospheric Response

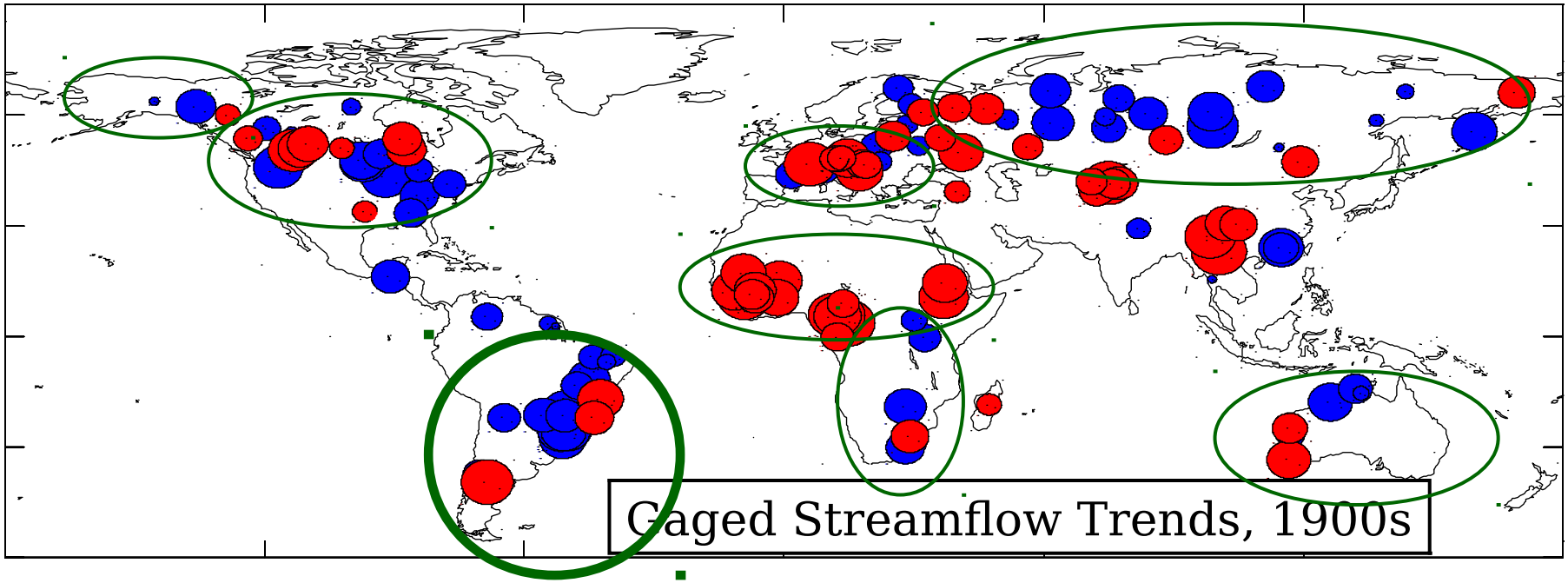


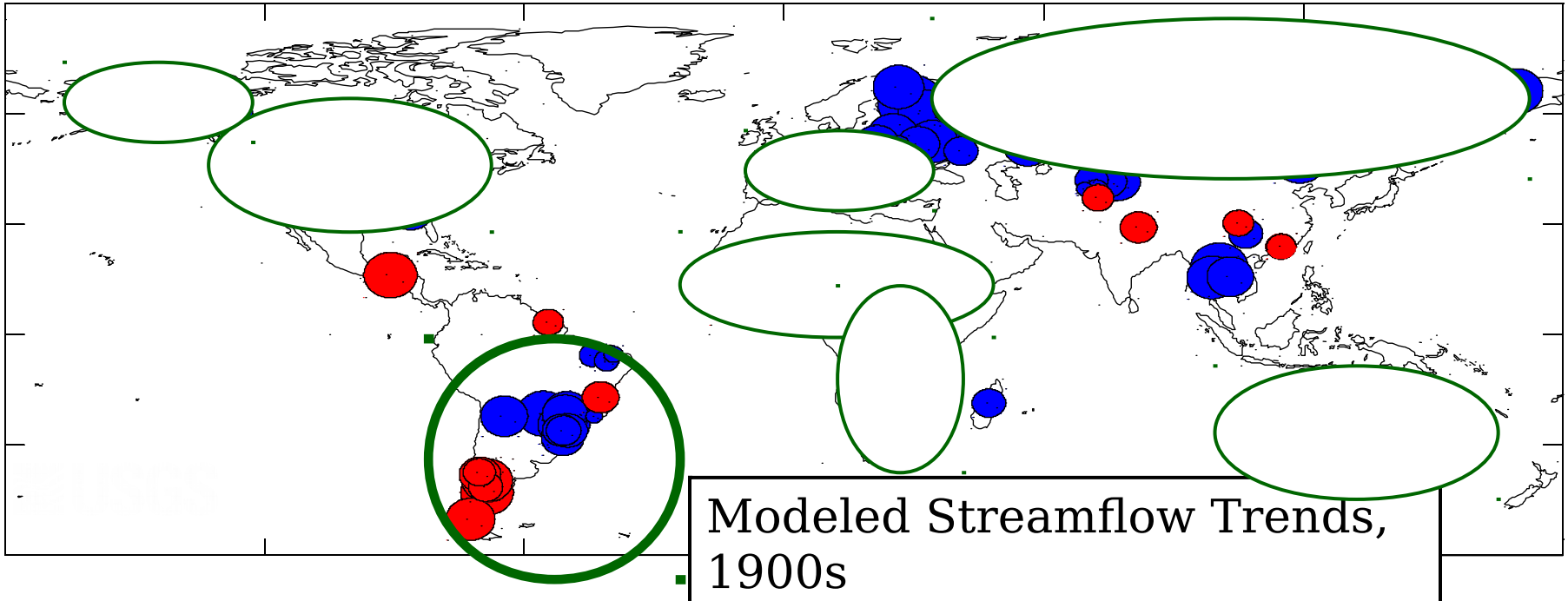
Atmospheric water content anomaly, 30S-30N over ocean; GFDL GCM; SMMR,SMM/I observations (Held and Soden, 2006)

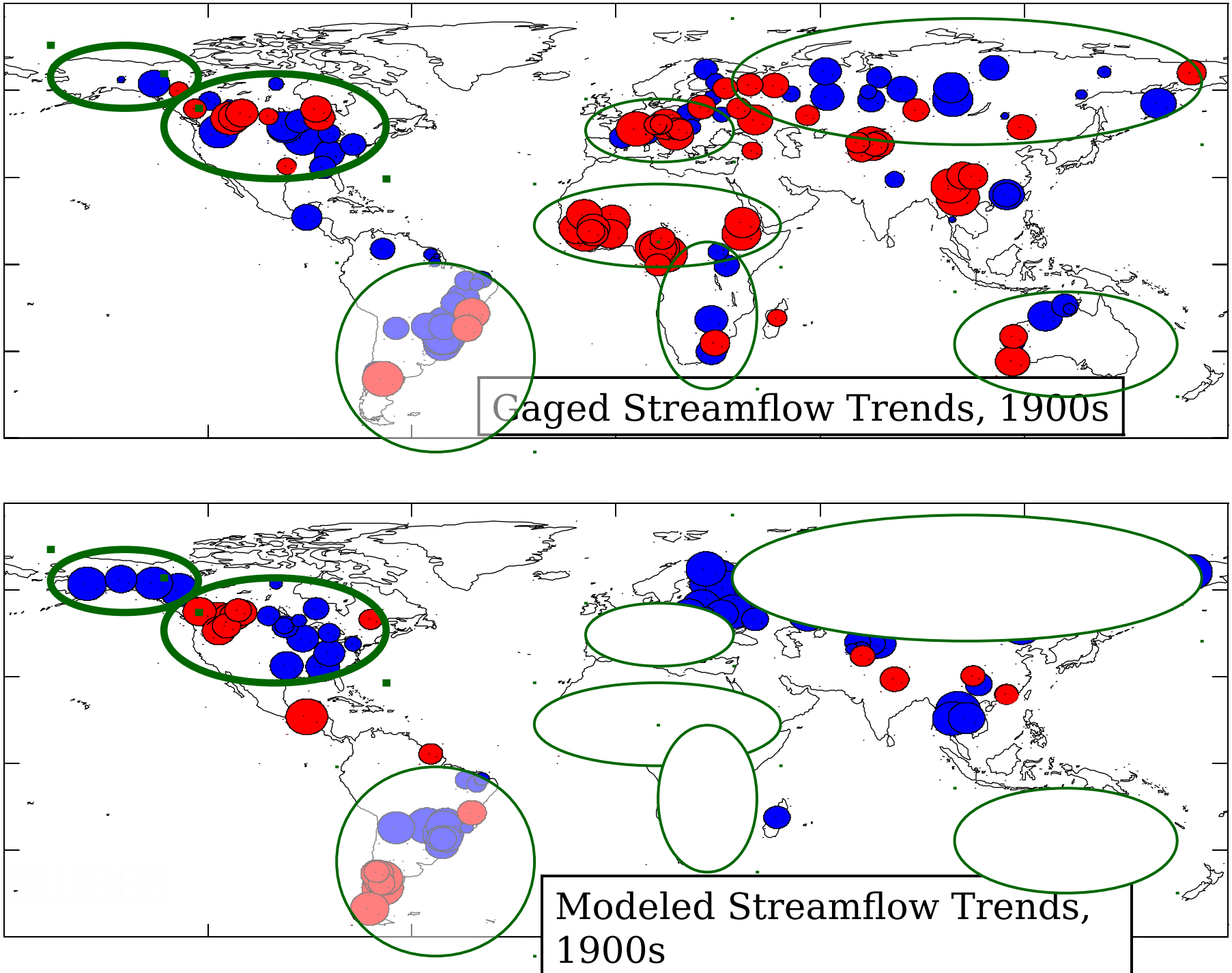

Gaged Streamflow Trends, 1900s
streamflow decreased
streamflow increased

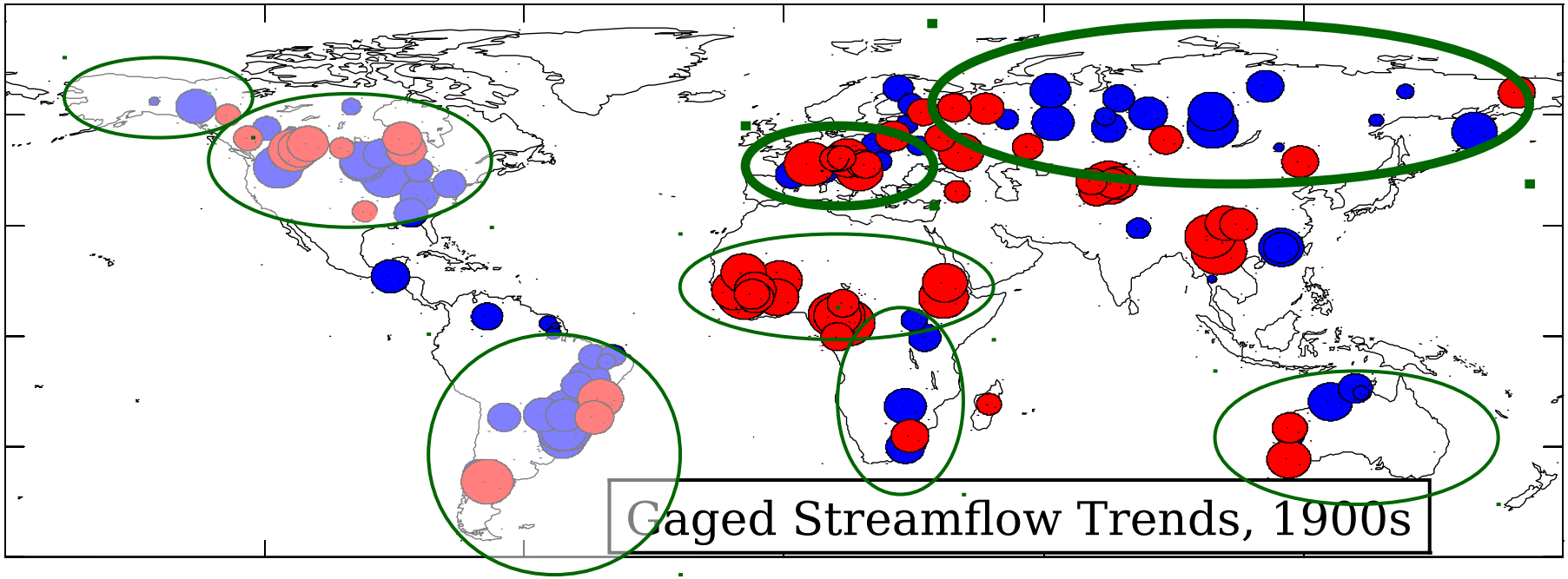

Gaged Streamflow Trends, 1900s

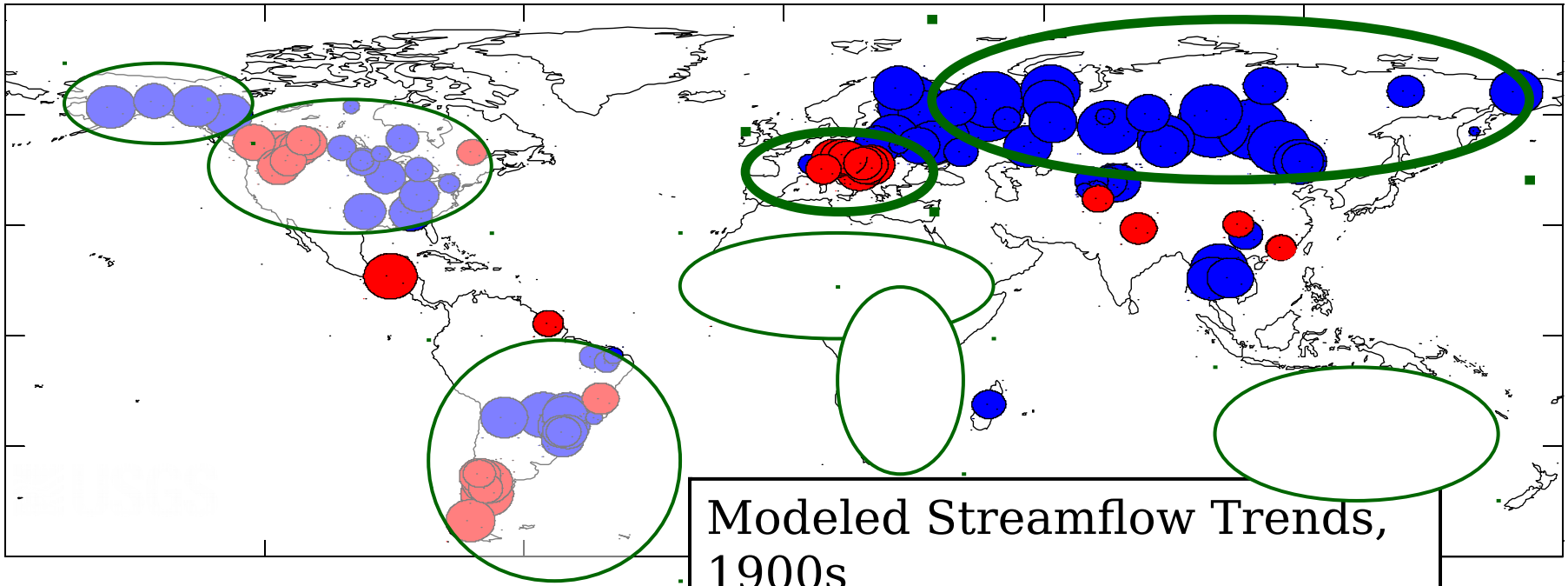

Modeled Streamflow Trends, 1900s

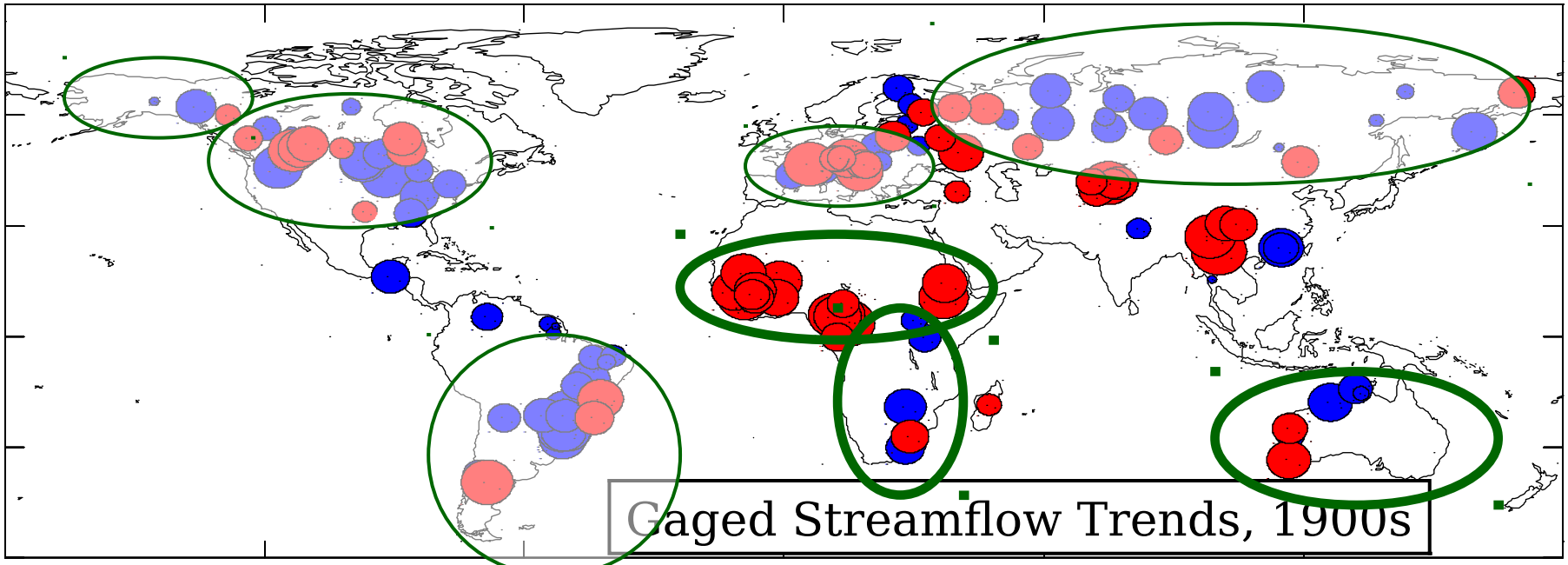

Gaged Streamflow Trends, 1900s

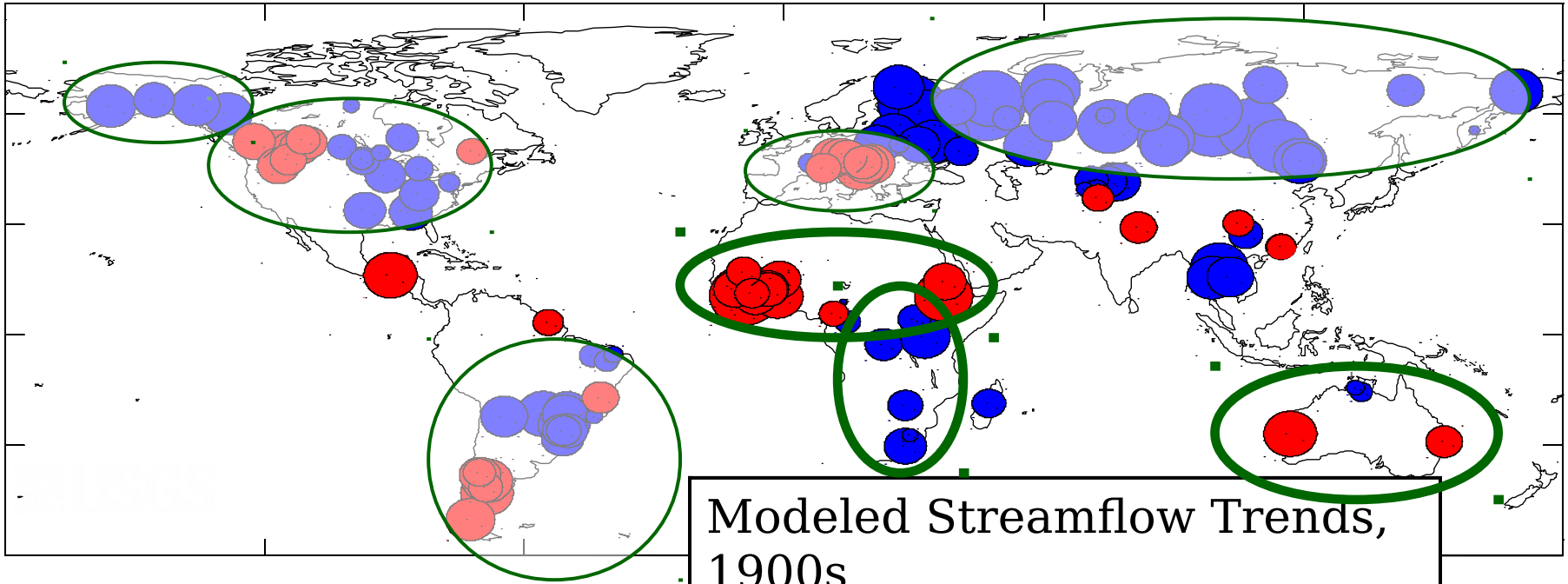

Modeled Streamflow Trends, 1900s

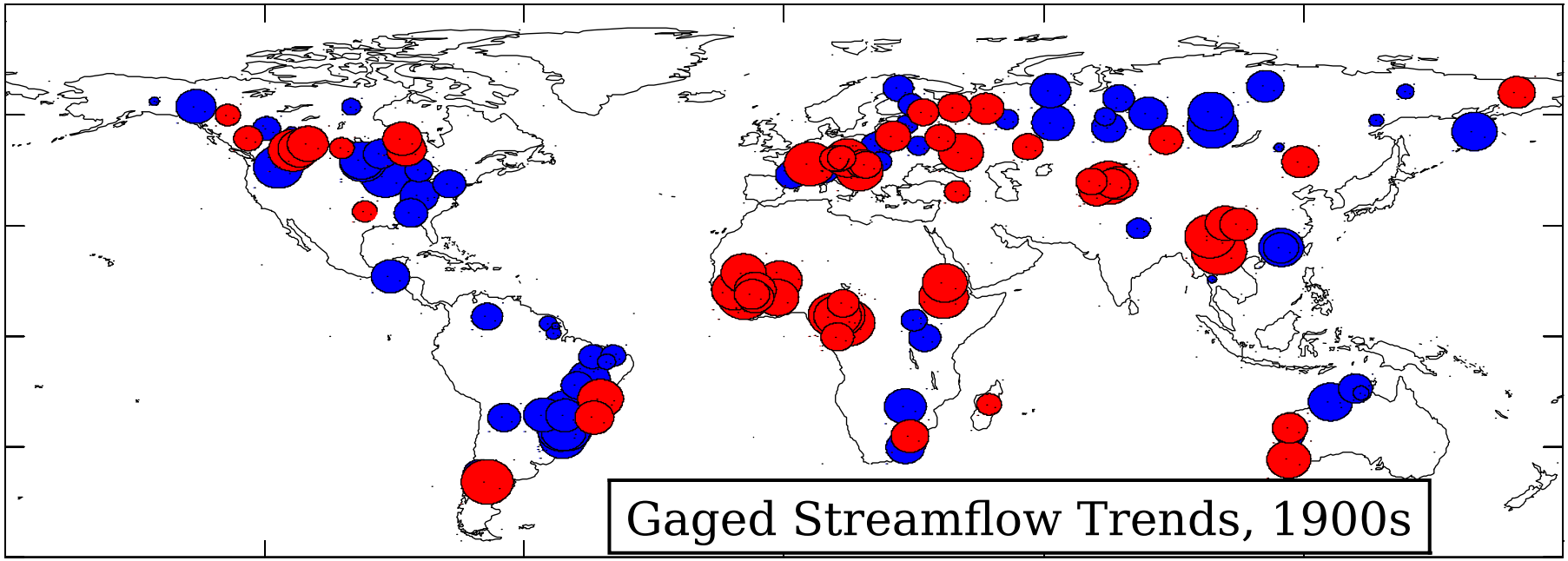

Gaged Streamflow Trends, 1900s
Modeled Streamflow Trends, 1900s

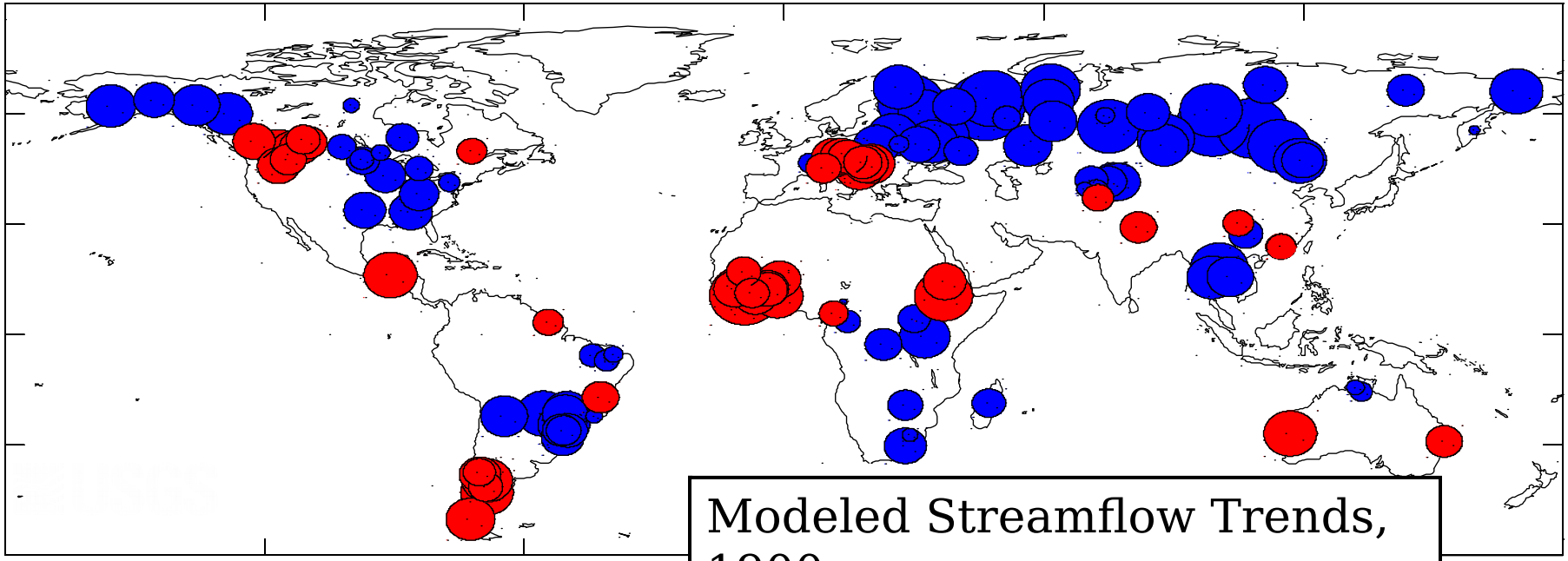

Gaged Streamflow Trends, 1900s


Modeled Streamflow Trends, 1900s


Gaged Streamflow Trends, 1900s

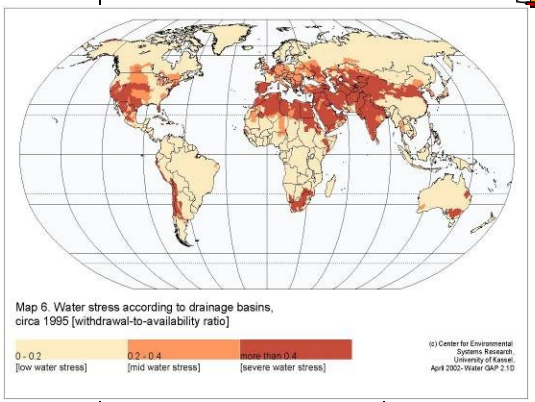

Modeled Streamflow Trends, 1900s


Gaged Streamflow Trends, 1900s

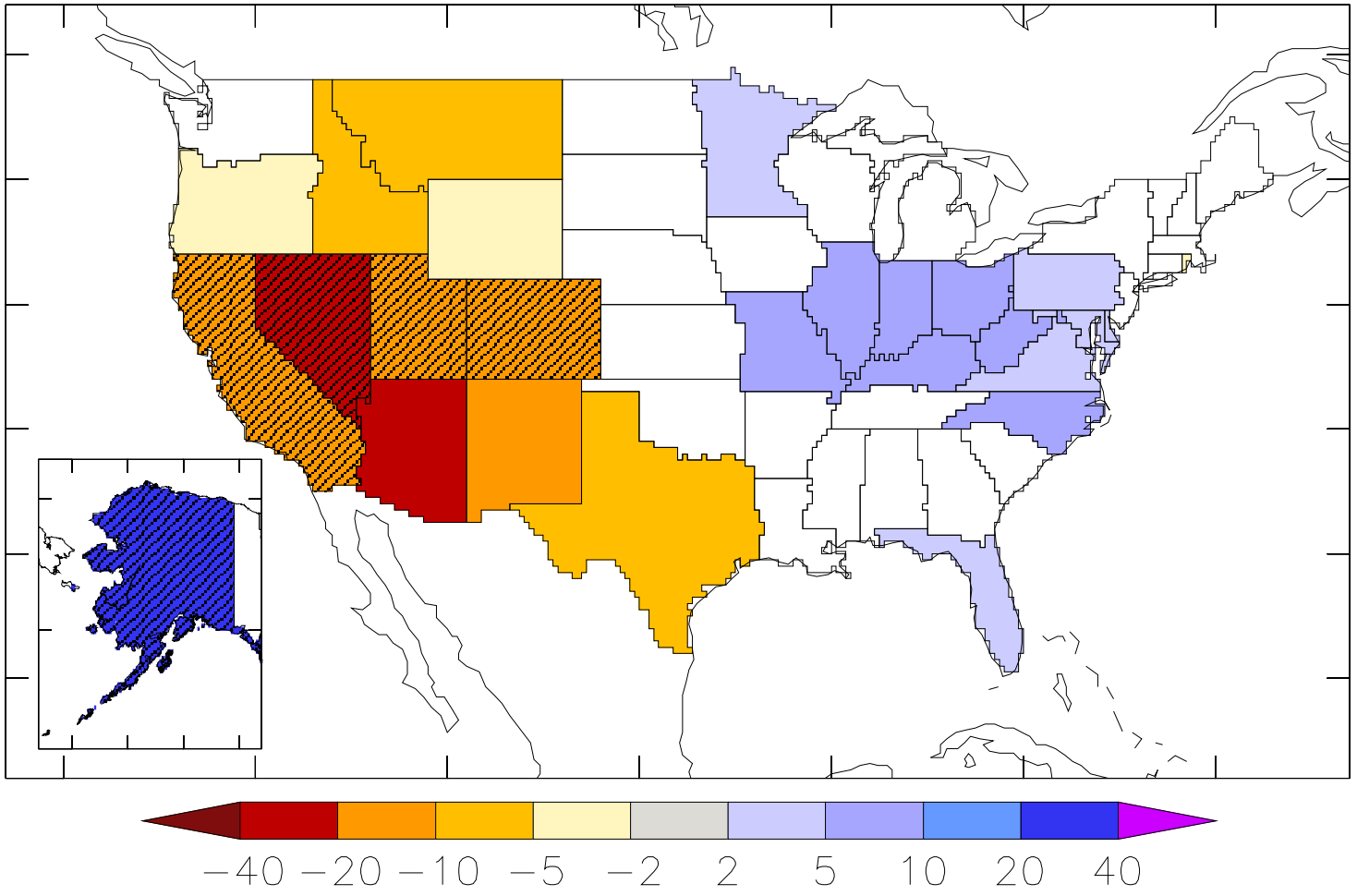

Modeled Streamflow Trends, 1900s

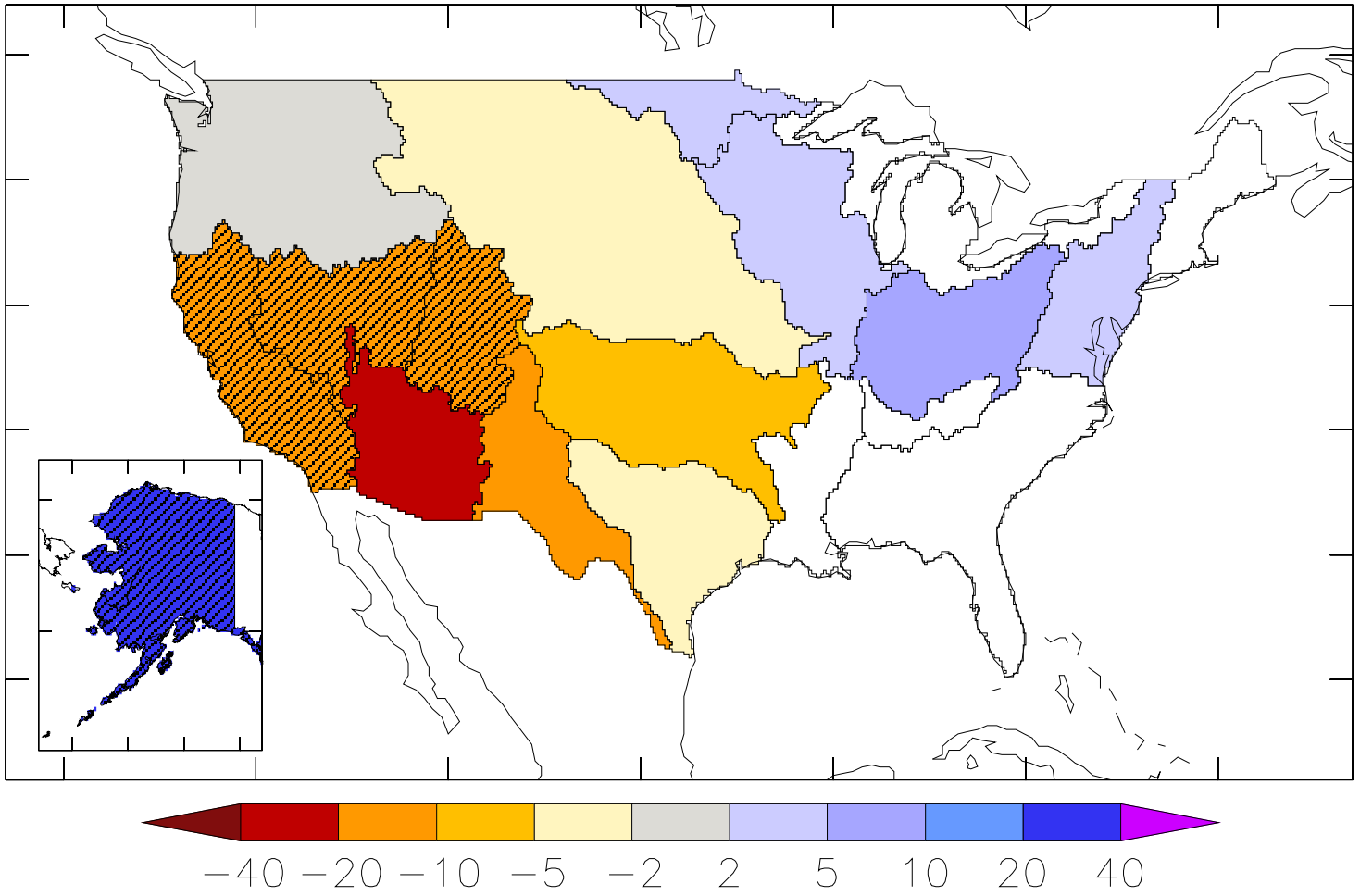
USGS

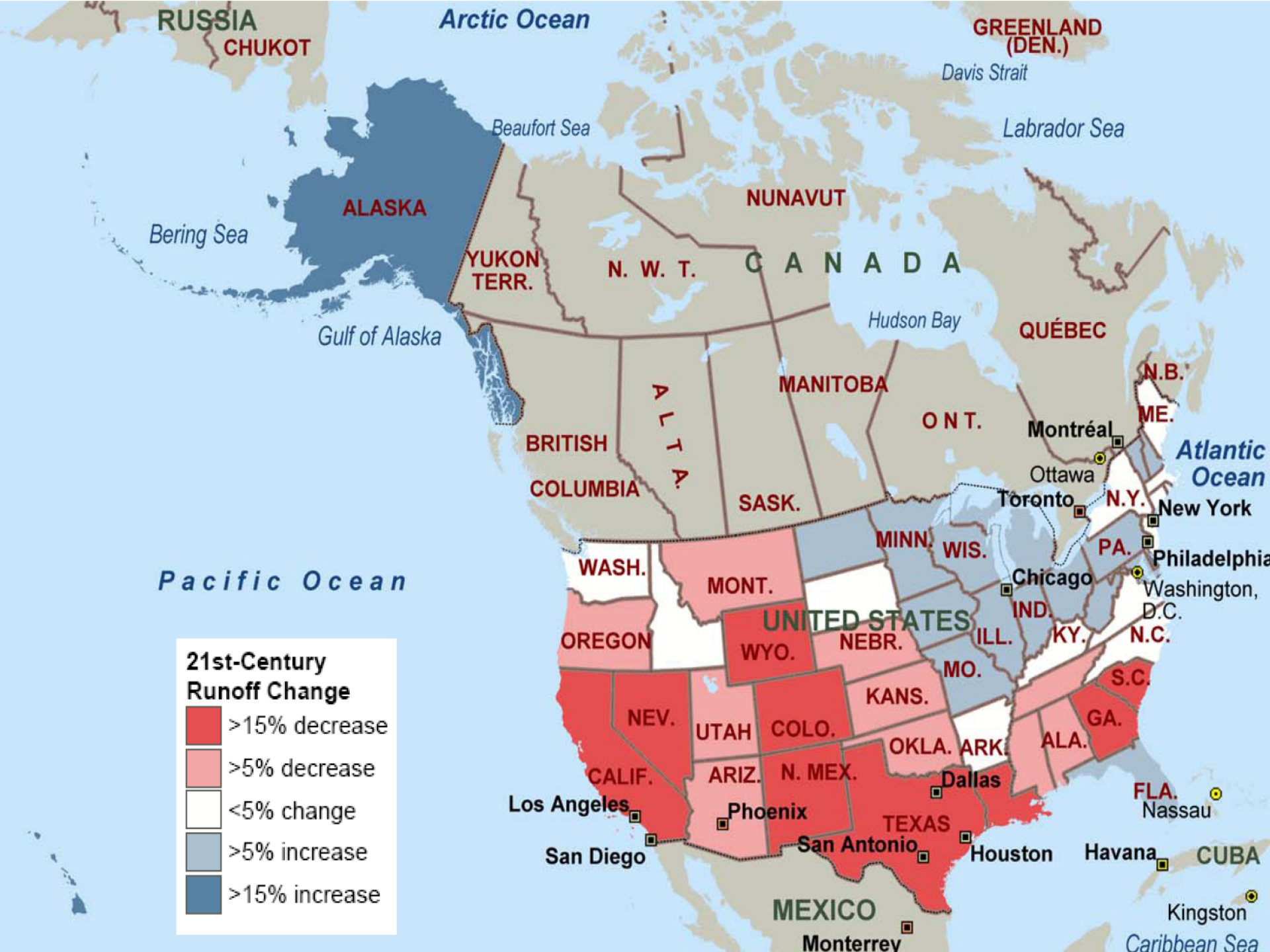
It now appears likely that a substantial part of global streamflow variability during the 20th century was not a random internal fluctuation of the climate system, but rather was caused by externally forced changes in climate.

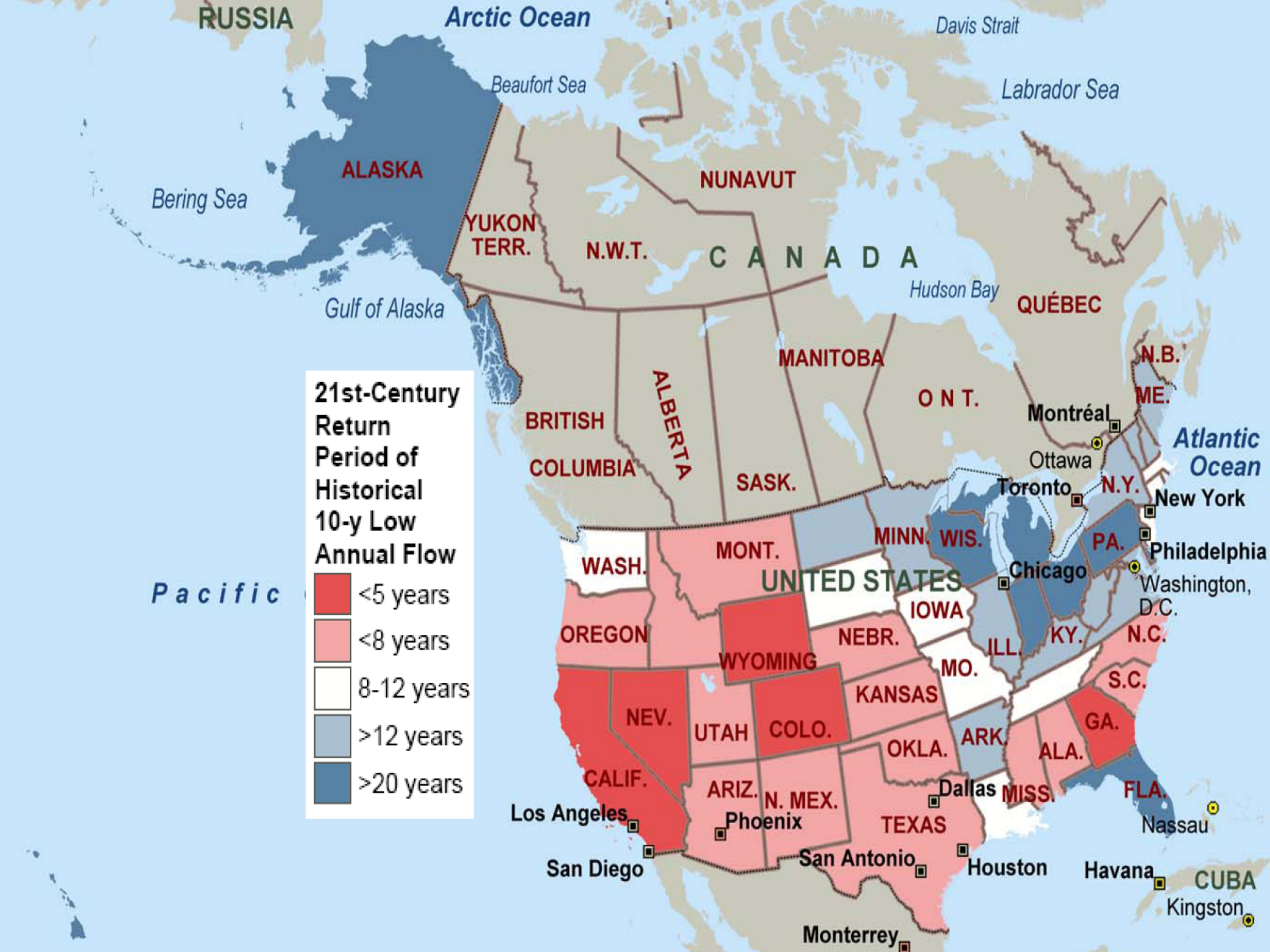

Map 6. Water stress according to drainage basins,
circa 1995 [withdrawal-to-availability ratio]
0 - 0.2
[low water stress]
0.2 - 0.4
[mid water stress]
more than 0.4
[severe water stress]
(c) Center for Environmental Systems Research, University of Kassel, April 2002 - Water GAP 2.1D

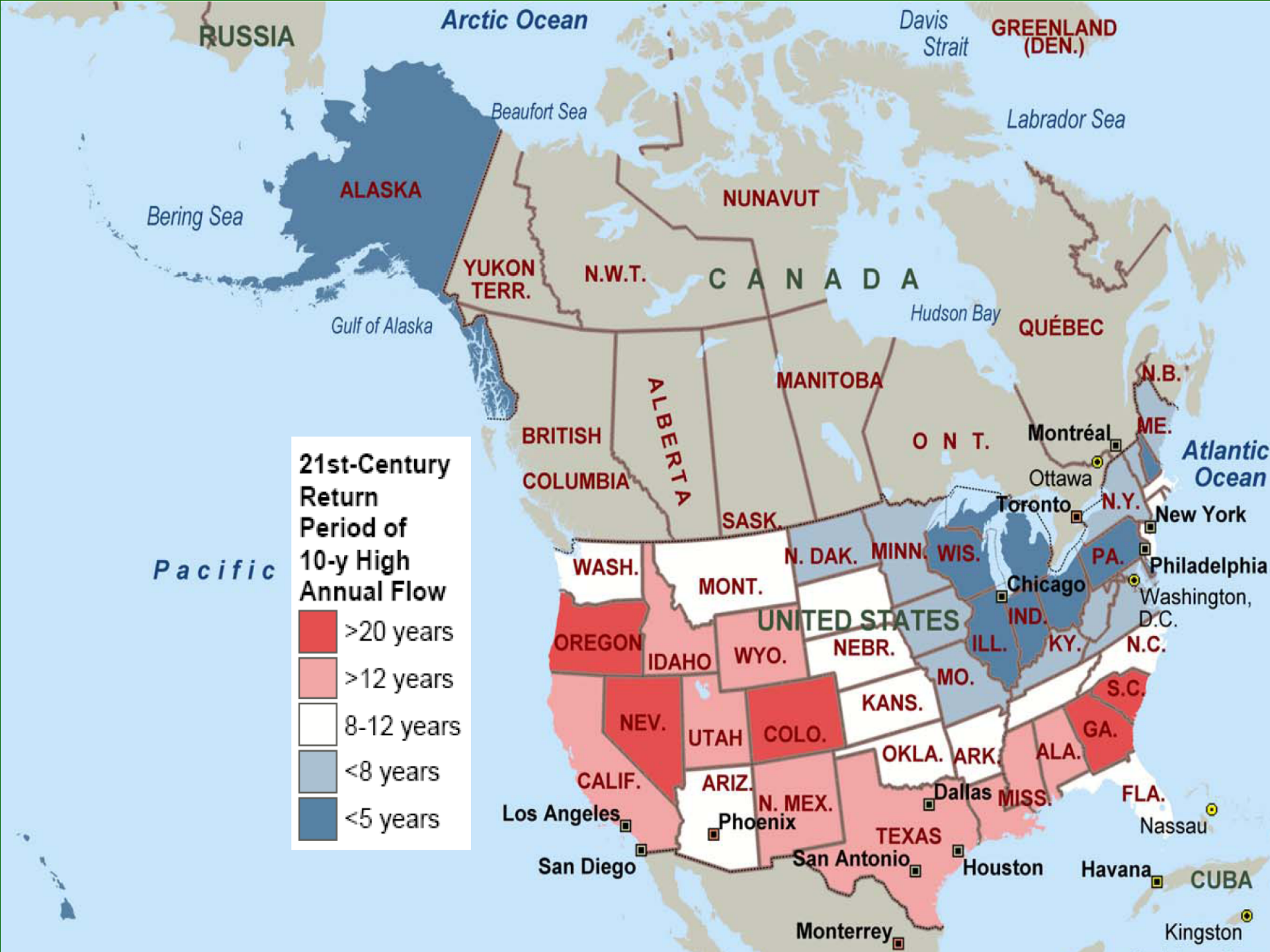
−40 −20 −10 −5 −2 2 5 10 20 40


−40 −20 −10 −5 −2 2 5 10 20 40


−40 −20 −10 −5 −2 2 5 10 20 40


RUSSIA
CHUKOT
Arctic Ocean
GREENLAND (DEN.)
Davis Strait
Beaufort Sea
Labrador Sea
ALASKA
Bering Sea
NUNAVUT
YUKON TERR.
N. W. T.
C A N A D A
Hudson Bay
QUÉBEC
Gulf of Alaska
MANITOBA
ALTA.
ONT.
N.B.
ME.
BRITISH COLUMBIA
SASK.
Montréal
Ottawa
Toronto
Atlantic Ocean
N.Y.
New York
MINN.
WIS.
PA.
Philadelphia
WASH.
MONT.
Chicago
Washington, D.C.
IND.
UNITED STATES
OREGON
WYO.
NEBR.
ILL.
KY.
N.C.
MO.
S.C.
KANS.
NEV.
UTAH
COLO.
GA.
OKLA.
ARK.
ALA.
CALIF.
ARIZ.
N. MEX.
Dallas
FLA.
Nassau
Los Angeles
Phoenix
TEXAS
San Antonio
Houston
Havana
CUBA
San Diego
MEXICO
Kingston
Monterrey
Caribbean Sea
Pacific Ocean
21st-Century Runoff Change
>15% decrease
>5% decrease
<5% change
>5% increase
>15% increase

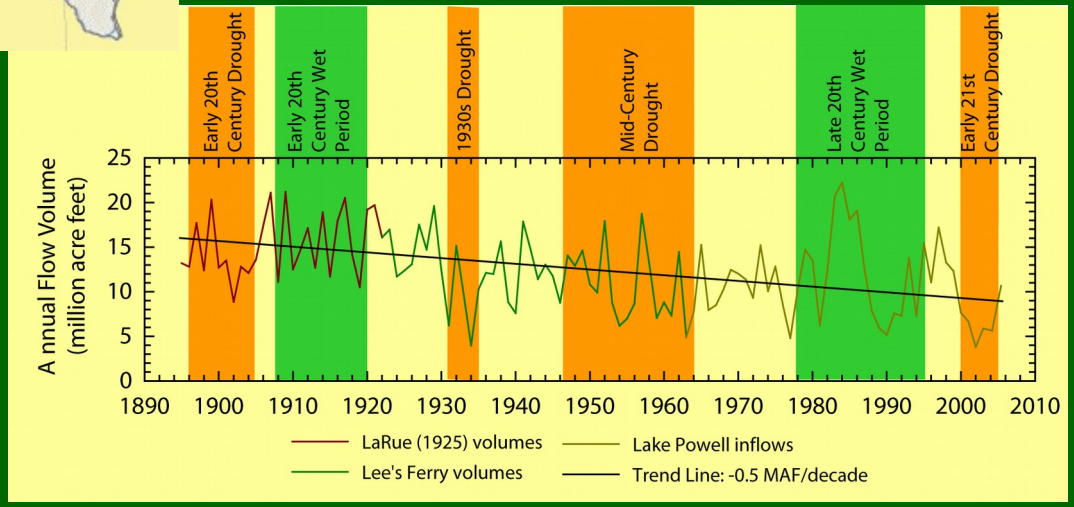

RUSSIA
Arctic Ocean
Davis Strait
Beaufort Sea
Labrador Sea
ALASKA
Bering Sea
NUNAVUT
YUKON TERR.
N.W.T.
C A N A D A
Hudson Bay
QUÉBEC
Gulf of Alaska
MANITOBA
N.B.
ME.
ONT.
BRITISH COLUMBIA
ALBERTA
SASK.
Montréal
Ottawa
Atlantic Ocean
Toronto
N.Y.
New York
MINN.
WIS.
PA.
Philadelphia
WASH.
MONT.
UNITED STATES
Chicago
Washington, D.C.
IOWA
OREGON
NEBR.
ILL.
KY.
N.C.
WYOMING
MO.
S.C.
KANSAS
NEV.
UTAH
COLO.
ARK.
GA.
OKLA.
ALA.
CALIF.
ARIZ.
N. MEX.
Dallas
MISS.
FLA.
Los Angeles
Phoenix
TEXAS
Nassau
San Diego
San Antonio
Houston
Havana
CUBA
Kingston
Monterrey
Pacific
21st-Century Return Period of Historical 10-y Low Annual Flow
<5 years
<8 years
8-12 years
>12 years
>20 years


RUSSIA
Arctic Ocean
Davis Strait
GREENLAND (DEN.)
Beaufort Sea
Labrador Sea
ALASKA
Bering Sea
NUNAVUT
YUKON TERR.
N.W.T.
C A N A D A
Gulf of Alaska
Hudson Bay
QUÉBEC
N.B.
ALBERTA
MANITOBA
BRITISH COLUMBIA
O N T.
Montréal
ME.
Atlantic Ocean
Ottawa
Toronto
N.Y.
New York
SASK.
N. DAK.
MINN.
WIS.
PA.
Philadelphia
WASH.
MONT.
Chicago
Washington, D.C.
UNITED STATES
IND.
OREGON
IDAHO
WYO.
NEBR.
ILL.
KY.
N.C.
MO.
S.C.
KANS.
NEV.
UTAH
COLO.
GA.
OKLA.
ARK.
ALA.
CALIF.
ARIZ.
N. MEX.
Dallas
MISS.
FLA.
Los Angeles
Phoenix
Nassau
TEXAS
San Antonio
Houston
San Diego
Havana
CUBA
Monterrey
Kingston
Pacific
21st-Century Return Period of 10-y High Annual Flow
>20 years
>12 years
8-12 years
<8 years
<5 years

Changes in Annual Runoff

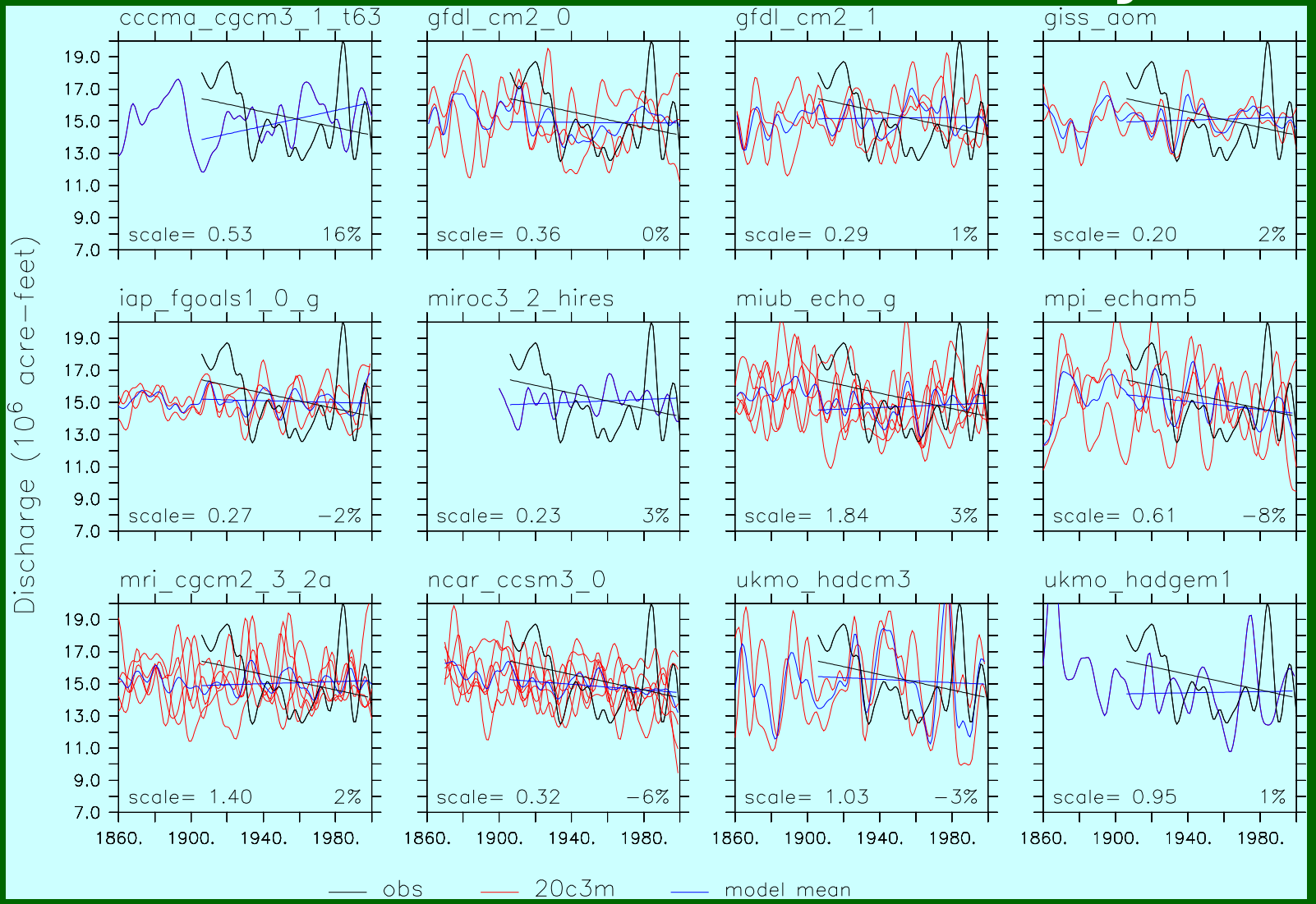
Colorado River at Lee's Ferry

USGS Fact Sheet 2004-3062,
Version 2, August 2004



USGS

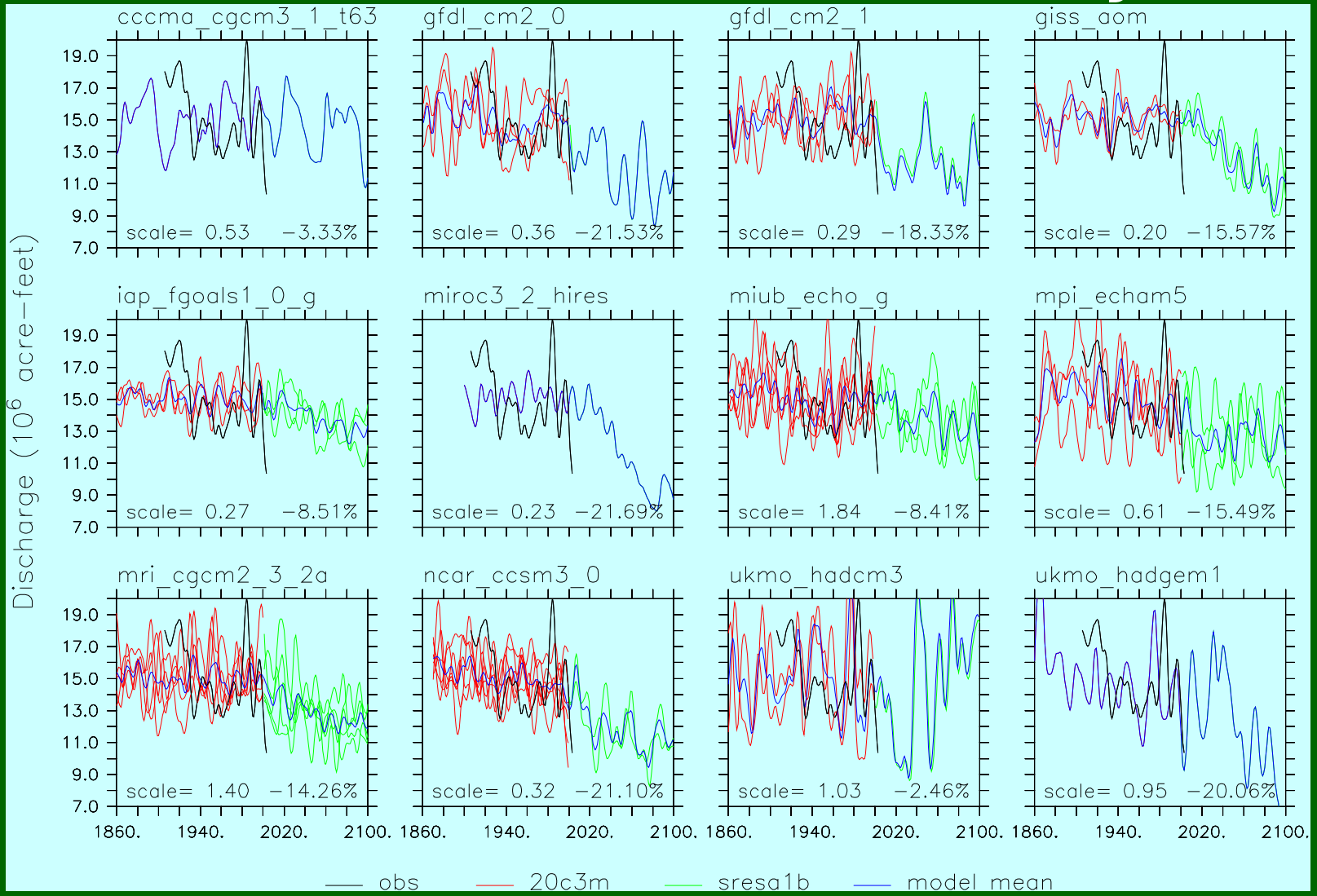
Colorado River at Lee's Ferry



USGS

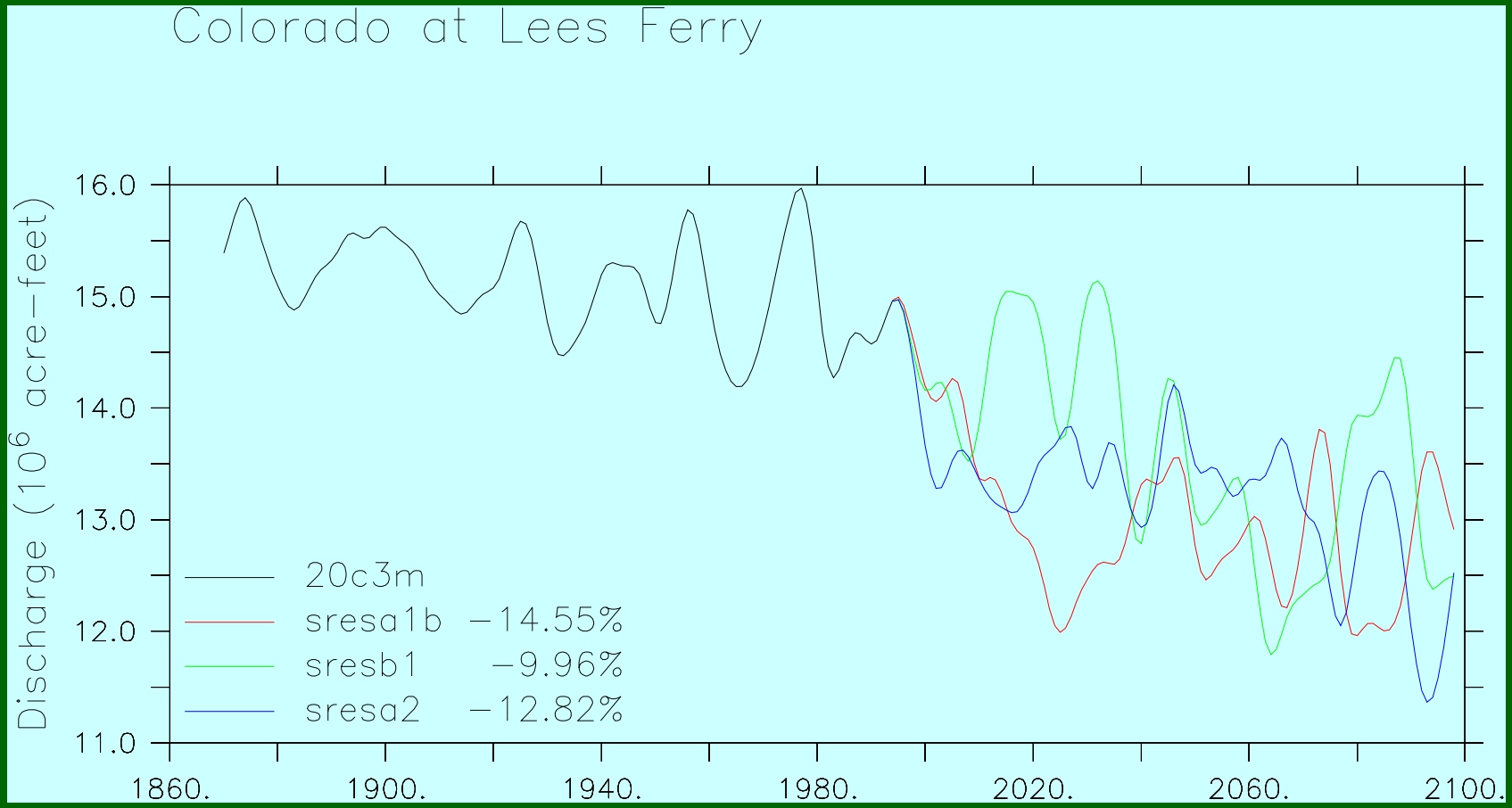
Model results are scaled to match adjusted flow record from Webb et al. (2005), which has linear slope of –16%/century.

Colorado River at Lee's Ferry



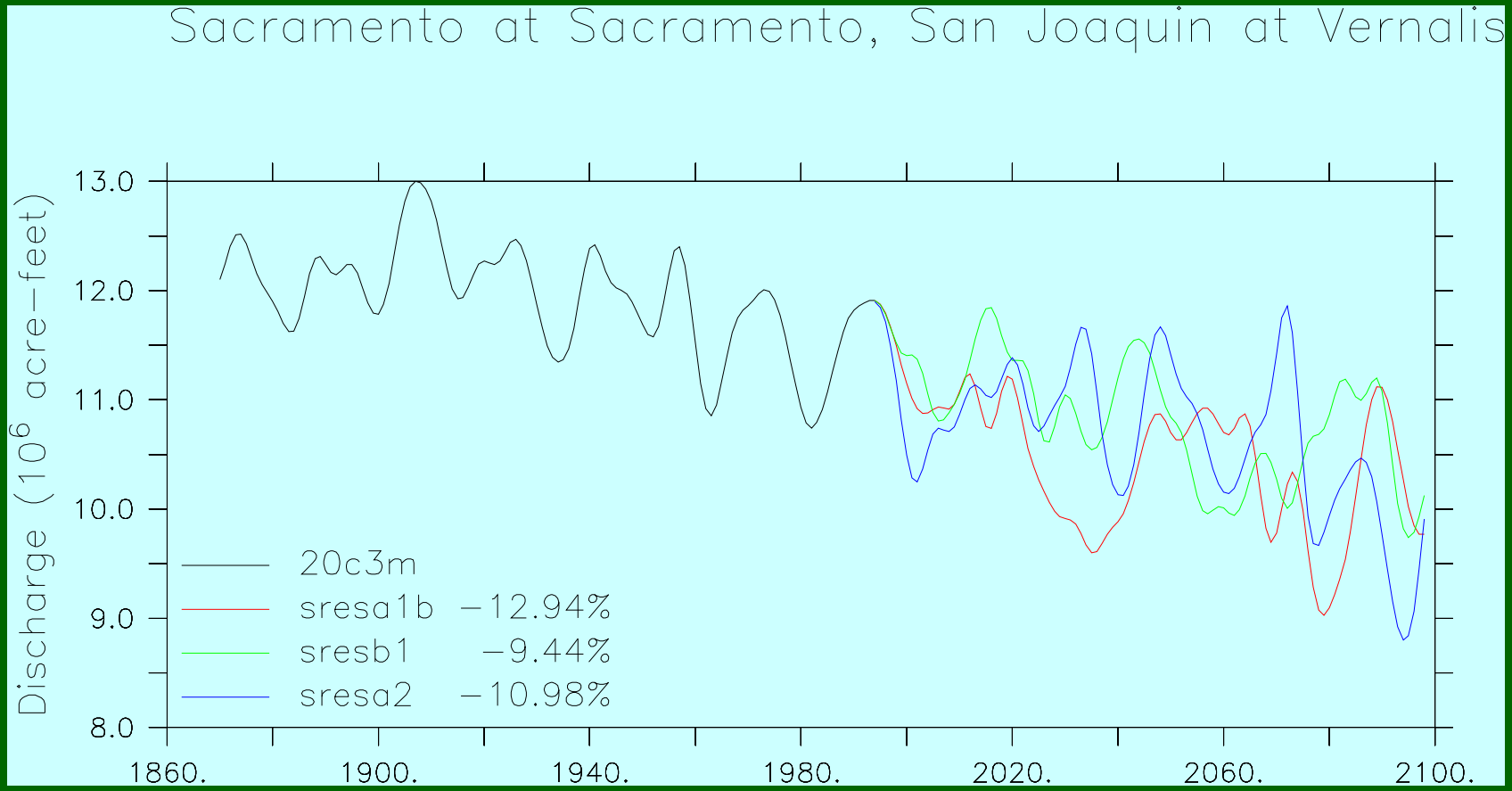
USGS

Colorado River at Lee's Ferry



USGS

Combined SF Bay Inflows



USGS

Concluding Comments

- Climate models have significant, though imperfect, skill in characterizing regional trends in mean annual streamflow.
- Climate models project substantial regional changes in mean annual streamflow for the 21st Century.

USGS